THE

KANSAS UNIVERSITY SCIENCE BULLETIN.

VOL. X, NO. 7—JANUARY, 1917.

(Whole Series, Vol. XX, No. 7.)

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LARVAL TREMATODES FROM KANSAS FRESH-WATER SNAILS, *Earl C. O'Roke.*

PUBLISHED BY THE UNIVERSITY,

LAWRENCE, KAN.

Entered at the post office in Lawrence as second-class matter.

7–111

KANSAS STATE PRINTING PLANT.
W. R. SMITH, State Printer.
TOPEKA, 1917.

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VOL. X, NO. 7.] JANUARY, 1917. [WHOLE SERIES VOL. XX, NO. 7.

Larval Trematodes from Kansas Fresh-water Snails.

BY EARL C. O'ROKE.

Thesis submitted in partial fulfillment of the requirements for the degree of master of arts in the Graduate School of the University of Kansas, 1916.

INTRODUCTION.

THIS study of larval trematodes was undertaken by the writer at the suggestion of Prof. Bennet M. Allen, in an attempt to add to the knowledge of this interesting group of parasites.

The snails used in the investigations were collected during the summer and fall of 1915 in connection with the Kansas State Biological Survey, and studies were made of the behavior and habits of the living cercariæ before the specimens were preserved for further morphological studies.

METHODS OF STUDY.

For convenience in transporting live snails, it was found desirable to tie the specimens in cheesecloth bags of twenty-five each, packing loosely in wet excelsior.

In the laboratory the snails were isolated in individual watch glasses and kept covered with water. Normally the cercariæ emerged within two or three days. Some of the infected snails were then preserved entire, and others were crushed for studies of living sporocysts and rediæ.

The fixatives used were a saturated corrosive sublimate solution with one per cent glacial acetic acid, Zenker's fluid, and four per cent formalin. The latter was discarded after trials proved the superiority of the other fixatives. Corrosive sublimate was preferable for free cercariæ.

Several different stains were used. Picrocarmine was excellent for studies of the living cercariæ. Specimens so stained could

sometimes be preserved by drawing glycerine under the cover slip with filter paper. For toto counts, Mayer's hæmalum gave the best results. The sections were cut from five to seven micra in thickness and stained with iron alum hæmatoxylin. Good results were also obtained by staining with hæmalum and using eosin or orange g. for counter stains.

The free cercariæ could be made to expand by heating slightly. When they were in this condition the fixing fluid was poured on suddenly, fixing the specimens in the best form for study.

The measurements given in this paper were taken usually from mounted specimens, and are not as accurate as those from living forms would be, because of shrinkage of the specimens during the process of fixing and mounting.

Amphistome Cercariæ.

Three species of amphistome cercariæ were found in my collections. For the first of these I propose the name *Cercaria cortii.*

Of twenty-three specimens of *Planorbis trivolvis* collected at Cherryvale, Kan., October 16, one was infected with *Cercaria cortii.* The snails were found adhering to rocks at a depth of from six inches to a foot in a large pond of clear water.

On October 17 the snails were isolated in individual watch glasses and kept covered with water, the water being changed each day. Cercariæ were noticed in one dish as follows, the observations being made in the morning at eight o'clock:

October 18	6 cercariæ.
October 19	12 cercariæ; all others encysted.
October 20	3 cercariæ; all other cercariæ encysted.
October 21	0 cercariæ; all other cercariæ encysted.
October 22	0 cercariæ; all other cercariæ encysted.
October 23	0 cercariæ; all other cercariæ encysted.
October 24	0 cercariæ; all other cercariæ encysted.
October 25	50 cercariæ; five encysted.
October 26	6 cercariæ; all others encysted.
November 2	All cysts still alive in water.
November 3	One new cercaria encysted.
November 4	One new cercaria encysting.
November 6	One new cercaria; all encysted.
November 5-7	No new developments.
November 8	Snail dead.

The cercariæ within the cysts were alive after having been kept in the water for twenty days, although only those that were opened within four days after they encysted, moved about.

One lot was allowed to dry for forty-eight hours, being kept in a covered watch glass. The air was moist, but there was no water covering the cysts. The cysts were covered with water and later opened. The cercariæ were alive and active. Longer and more complete desiccation proved fatal to the cercariæ.

The process of encysting was carefully noted for this species. The swimming ceases; the anterior end of the body is directed downwards or towards the side of the container; the oral sucker becomes attached; the tail vibrates rapidly, then the cercaria loosens its hold and goes through creeping motions, but does not swim any. This process is repeated a few times, then the cercaria flattens itself against the glass and assumes a spherical shape. The head is twisted from side to side within the cyst wall, and the tail continues to vibrate. The worm becomes more transparent and the cercaria seems to loosen from the outer wall, which assumes a furry appearance, due to the giving off of cystogenous material by the cystogenous glands. At this time, the cercaria begins peculiar rotating movements, which continue from an hour and twenty minutes to two hours and ten minutes. The motion consists of a series of intermittent movements. The time required for a cercaria to make a complete turn varied from one and three-fourths minutes to two and a half minutes, with from thirteen to twenty-two separate movements in a revolution.

The cyst wall becomes thicker and more transparent. Sometimes the tail loosens and swims away, while at other times it may remain loosely attached to the cyst. One tail vibrated constantly for eight hours after the cercaria began to encyst. The tail as well as the body gives off cystogenous material, which is in the form of a delicate sheath surrounding that organ and at a distance of one-half the width of the tail from it.

The motions of the encysting cercaria become slower and slower, and finally cease as the process is completed. When the cyst is fully formed it is much more transparent than the free-swimming cercaria, and the worm is coiled within the cyst with its anterior and posterior ends in contact. Slight spasmodic motions within the cysts can be noted for three or four days after encystment. Sometimes the cercaria breaks out of its cyst by rupturing the wall, and forms a new cyst. The cercariæ usually encysted on the bottom and sides of the watch glass nearest the window, and were shaped like a deep plano-convex lens. In a few cases where encystment took place among masses of snail fæces and

not against the side of the container, the shape of the cysts was ellipsoid.

Cercaria cortii is a rapid swimmer, and its swimming motions are strikingly regular. It would often propel itself in a straight line from one side to the other of a Syracuse watch glass. Creeping motions were rather infrequent in open water, but under the cover slip this was the usual method of locomotion.

The measurements of this cercaria were taken from preparations mounted in glycerine and glycerine jelly after the specimens were killed by heating slightly, and represent as accurately as possible the size of the form in life.

This cercaria is elongate, oval, and wider at the posterior than at the anterior end. It is capable of assuming shapes varying from spherical to long and narrow. The length of the body is .94 mm. and the length of the tail is .87 mm.; a total length of 1.81 mm. The width of the acetabulum is .25 mm. and the width of the oral sucker is .08 mm. The edge of the oral sucker presents a finely lobated appearance.

The mouth is situated within the oral sucker and opens into an oral cavity .01 mm. wide and .06 mm. long. This is separated from the esophagus by a constriction. The esophagus narrows into a pharynx about one-third the diameter of the oral cavity. It is surrounded by a band of longitudinal muscle fibers .027 mm. in outside diameter. The width of the digestive diverticula is .017 mm.

Fig. 2, a cross section through the region of the eyespots, shows the brain. The nerve cords could not be traced any distance from this region.

The anterior one-third of this cercaria is heavily pigmented with dark pigment.

The esophagus is long and narrow. The digestive tract extends five-sevenths of the length of the body. The two eyespots are prominent and are .028 mm. in diameter and .16 mm. apart. The tubes of the excretory system extend from near the eyes to just in front of the acetabulum.

The excretory tubes are made up of large flame cells, irregularly joined together, and very closely associated with the digestive tract. In the living form these tubes appear to be cylindrical and rather regular in shape, but cross sections of the fixed specimens (fig. 3) show the true nature of these ducts. In some places they seem to take a spiral course around the diverticula of the digestive tract. These cells contain concretions .007 mm. in diameter.

In the living form these concretions look like highly refractive cell nuclei and mark out the excretory tract very distinctly. The excretory vesicle into which the paired tubes open is just anterior to the acetabulum and is .017 mm. in diameter.

From the living specimen one would think that the tail contains an excretory canal, but cross sections show that the central region of the tail is made up of very large cells with extremely delicate walls. Encircling this central region is a cylinder of smaller cells and a narrow band of outer longitudinal muscle fibers.

The anlagen of the reproductive organs show as rounded masses of deeply staining cells, within the diverticula of the digestive tract. Cystogenous glands are present all over the body excepting in the immediate vicinity of the oral sucker and mouth. Within the cystogenous glands are granules of the cyst-forming material.

Of twenty-three specimens of *Planorbis trivolvis* collected at Lawrence, Kan., October 10, one was infected with *Cercaria diastrophora* Cort. The following additional description and accompanying plates may be considered merely supplemental to Cort's description of this form. These studies were made before the identification of the species had been established as being the same as *C. diastrophora* Cort.

In general appearance this form corresponds to *Cercaria cortii*, but it is much smaller, measuring .48 mm. long and .2 mm. wide. The tail is .58 mm. long. The oral sucker is small, measuring .06 mm. in width, while the acetabulum is exceedingly large, measuring .15 mm. in outside diameter.

The esophagus is very slender, opening into a bulbous pharynx three-fourths as broad as the tip of the oral sucker. The eyespots are prominent and are oval rather than spherical, measuring .027 mm. by .036 mm. They are separated by a distance equal to the long axis of the eye.

The excretory system consists of paired ducts opening into an excretory vesicle anterior to the acetabulum. This vesicle also receives smaller ducts from the region of the acetabulum. The excretory pore opens on the dorsal surface.

This species stains deeply with hæmalum, excepting in the region of the oral sucker, where the cells seem to be devoid of nuclei. The tail is made up of large central cells surrounded by a ring of smaller cells. It contains no excretory canals.

The immature cercariæ of this species are blunt-tailed and clumsy. No internal organs can be distinguished excepting the eyespots, which are rudimentary.

The rediæ of this form are short and blunt and are provided with anterior and posterior locomotor projections. The digestive tract is short and blunt. The cercariæ within the rediæ were all immature, due perhaps to the fact that the snail was not fixed until cercariæ had ceased to emerge from it. The rediæ average .88 mm. long and .25 mm. wide.

Of twenty specimens of *Planorbis trivolvis* collected at Lawrence, Kan., July 22, one was parasitized with *Cercaria inhabilis* Cort. These snails were obtained from the surface of Horseshoe lake, where they were attached to twigs and floating objects.

The cercariæ emerged from the snails that had been isolated in a watch glass, and remained in the immediate vicinity of the snail. Owing to their heavy tails and unwieldy bodies, their attempts at swimming resulted in their floundering about. The creeping motions also were very feeble. When the snail was crushed, rediæ and cercariæ in various stages of development were found in the liver. A remarkable fact in connection with this species was that the rediæ were smaller than the cercariæ.

This apparent inconsistency may be explained by comparing the free cercariæ with the sections of the infected snail liver, where free cercariæ are to be found completing their development in the digestive gland near the periphery of that organ.

The length of this species is .76 mm. and the width is .23 mm. There are two prominent pigment spots on the anterior dorsal surface of the body. The digestive tract consists of a slender pharynx leading from the mouth, situated within the oral sucker, to the diverticula of the intestine. The excretory system consists of paired tubes opening into the excretory pore just anterior to the ventral sucker. A mass of deeply staining cells, the anlage of the reproductive organs, is anterior to and below the pore.

The rediæ are elongated sacs, the immature ones averaging .55 mm. long and .07 mm. wide. The mature ones are slightly longer and twice as wide. The immature forms contain only germ balls, while the mature ones contain both germ balls and developing cercariæ that move about within the walls. No mature cercariæ were observed within the rediæ of this species.

Distome Cercariæ.

In my material are nine distome cercariæ, belonging to five subgroups.

MEGALUROUS CERCARIÆ.

Of twenty specimens of *Planorbis trivolvis* collected at Lawrence, Kan., July 27, one was infected with *Cercaria magnacauda*. This is an active free-swimming form, positively phototropic. It did not undergo creeping motions excepting when the tail was detached from the body.

The behavior of this cercaria was noted carefully. They would swim actively for a few minutes, then come to rest, pointing head downwards at an angle of fifteen degrees from the vertical. In this position the tail is blade shaped and flattened dorsoventrally. Practically all of the cercariæ would be either resting or swimming at any one time. These cercariæ were especially virile, living from thirty to forty-eight hours after emerging from the snail. The tail invariably became detached from the body and continued swimming after the death of the former. This form did not encyst.

The rediæ of this species were found in tangled masses in the liver of the host. They average .9 mm. long and from .1 mm. to .5 mm. wide, having a short digestive tract. The mouth is terminal and well defined, being provided with a large median stylet.

This remarkable cercaria has a total length of 1.56 mm., the body comprising only .127 mm. leaving it less than one-eleventh of the length of the tail. These measurements, which were taken from balsam mounts, are approximately normal, excepting that the tail is somewhat flattened.

From a study of the living material only the suckers and the concretions in the excretory ducts could be seen. Mounted specimens show the enormous excretory tract and the reproductive anlagen, while the cephalic glands can be seen in sections.

The excretory tract consists of two tubes extending from near the oral sucker to a large excretory bladder, posterior to the ventral sucker. This bladder communicates with another in the anterior narrow part of the tail. Opening into this secondary bladder is the median excretory duct of the tail, which is ventral in position.

The reproductive anlagen appear as two masses of cells anterior and posterior to the ventral sucker. No digestive tract could be traced.

The oral sucker is .007 mm. in outside diameter, while the ventral sucker is twice this size. The tail is made up of large parenchymous cells and longitudinal and cross-muscle fibers. Owing to its delicate structure it could not be embedded for sectioning.

ECHINOSTOME CERCARIÆ.

Of one hundred specimens of *Physa gyrina* collected at Lawrence, Kan., August 19, one was infected with *Cercaria fusiformis*. This species is characterized by a symmetrical spindle-shaped body with a long digestive tract extending from the oral sucker to near the caudal end of the body. While this species had all of the characteristics of the echinostome cercariæ, no spines are present anywhere. The region of the oral sucker presents a collared appearance. The total length of this cercaria is .77 mm. and the width is .07 mm. The oral sucker has an external diameter of .028 mm. and an internal diameter of one-fourth that size. The ventral sucker is about the same size and is capable of being greatly extended or projected. This form used the ventral sucker extensively in holding fast to the substratum.

The digestive diverticula do not inclose the ventral sucker as one would infer from the dorsal aspect, but are dorsal to it in lateral view. The digestive tract consists of a very narrow esophagus leading from the mouth to the pharynx. Just back of the pharynx is a median intestine extending as far as the anterior end of the ventral sucker, where it branches into two diverticula that extend back to the posterior end of the body. The esophagus measures .003 mm. wide and .03 mm. long. The width of the pharynx is .018 mm. and that of the intestine .012 mm.

The excretory tract consists of narrow paired tubes extending from the region of the pharynx to the posterior end of the body. The excretory bladder and the excretory duct, in the anterior part of the tail, could not be traced definitely, but appeared as more transparent areas in the toto mount.

The anlage of the reproductive organs is a dense mass of cells near the posterior end of the body.

The posterior sucker is very muscular. The figures accompanying the plate show this sucker open, closed, and extended.

The rediæ are large and contain from six to eight mature cercariæ, together with a few large germ balls. They are distended in places by the cercariæ contained within. The average measurements of the rediæ are, length 1.91 mm. and width .13 mm. to .33 mm.

GYMNOCEPHALOUS CERCARIÆ.

Of fifty specimens of *Physa integra* collected at Chanute, Kan., October 17, two were infected with *Cercaria gracilis*. I propose this name because of the ability of the species to draw itself out

into a very slender shape. The infection was slight, and these studies were made entirely from the living material and two mounted specimens.

This cercaria is exceedingly active and is capable of extending the body until it is as narrow as the tail. This form can also extend the ventral sucker until it appears prominent in a lateral view. In a characteristic position this form is slender, heart-shaped. The oral sucker is minute, the ventral sucker being four times as large.

The esophagus is slender and has a fold near the anterior end. Just beneath the fold is the narrow pharynx.

The diverticula of the digestive tract are broad, encircling the ventral sucker. The excretory system could not be made out, but paired rows of cells with highly *refractive* nuclei, or possibly concretions, mark this tract. The tail is broad and large, being one-third the width of the body and a little over twice the length of the same. The entire length of this cercaria is .53 mm.

The rediæ are of unusual shape, tapering at both ends with a definite collar near the anterior end. The digestive tract is slender, extending about half the length of the body. Within the rediæ are germ balls, developing cercariæ, and mature cercariæ. The dimensions of the rediæ are 1.6 mm. long and .33 mm. wide in the widest place.

FURCOCERCOUS CERCARIÆ.

Two per cent of large numbers of *Physa gyrina*, 436 in all, collected at Lawrence, Kan., during the months of July and August, from Haskell pond and the lake at Lakeview, were parasitized with a form for which I propose the name *Cercaria inversa*, because of its being directed tail foremost in swimming. The cercariæ emerged freely from the snails and flitted about rapidly in the water with a peculiar vibratile motion, directed tail foremost. Creeping movements were not observed excepting under the cover slip, when the tail became severed from the body. When the parasitized snails were crushed, rediæ containing cercariæ in all stages of development, from mere germ balls to mature forms, were present. The various stages in the development of the cercariæ could be easily observed because of the characteristics of the tails, which varied in length from mere stubs and rounded lobes to the elongate bifurcated tails of the mature forms.

The rediæ* were in a tangled mass in the liver. The largest

* Further studies showed that the rediæ of this species may be four times as long as the one shown in figure 47, and much constricted, resembling link sausage.

ones exhibited a slightly waving motion. Under the cover slip cercariæ emerged from the rediæ, usually tail first, from the birth pore near the anterior end. It required about two minutes for a cercaria to free itself from the redia. This form did not encyst, but the cercariæ soon died in the water, in no case living more than four hours after emerging from the snail. Those liberated when the snail was crushed lived only from eight to twelve minutes. The number of this species emerging from a single snail was estimated at five thousand.

Cercaria inversa is a small furcocercous form, corresponding as to size, shape and behavior to *Cercaria douthitti* described by Cort (1915), from *Lymnaea reflexa*. This species, however, contains no eyespots and is found in rediæ instead of sporocysts. The length of the body is .16 mm. in well-extended specimens, and the width is .045 mm. The unbranched part of the tail has a length of .26 mm. and a width of .027 mm., while the lobes are five-sixths as long as the main part of the tail and one-half as wide. These lobes taper to rather a sharp point. The openings in the suckers are about the same size, .01 mm., but the outside dimensions of the oral sucker are greater than those of the ventral sucker. The measurements are, oral sucker .042 mm. and ventral sucker .028 mm.

As in *Cercaria douthitti*, the region back of the center is filled with large cephalic glands. The ducts of these glands extend forward and open alongside the oral sucker (fig. 50). The excretory system of the body region could not be traced, but a duct extends through the main part of the tail and is joined by ducts from each branch. An excretory pore opens to the exterior between the forks of the tail.

The anlage of the reproductive organs is a mass of small cells near the posterior end of the body and ventral in position.

Six per cent of large numbers of *Physa gyrina* collected at Lakeview, Kan., August 20, were infected with a form for which I propose the name *Cercaria echinocauda*. Collections of snails from the same locality, made October 12, showed two per cent to be infected.

This cercaria was very active, swimming both forwards and backwards, but usually forwards, with a vibratile motion of the tail. The tail was loosely attached to the body and was easily severed. When this occurred the body died in about twenty minutes, while the tail lived for two hours, swimming about

actively. Six hours was the maximum time that these cercariæ remained alive after emerging from the snail.

The body of this species is .31 mm. long and .125 mm. wide. The main part of the tail has a length of .54 mm., while the branches are .18 mm. long. Two large eyespots are present. They are made up of minute pigment granules and measure .02 mm. by .014 mm. in dorsal view, being longer in the transverse direction.

An excretory tube begins in the branches of the tail and extends throughout the length of that organ to the excretory pore in the posterior end of the body. The excretory tract could not be made out in the body region.

The branches of the tail are provided with a sort of fin extending around the tip. This fin is beset with minute spines.

A mouth is present in the oral sucker, but there is no digestive tract leading from it.

The anlage of the reproductive organs is ventral in position and near the posterior end of the cercaria.

A peculiar characteristic of this species was that in the fixed specimen the tail is usually bent sharply at its junction with the body.

The rediæ of this species average .2 mm. long and .11 mm. wide. They are filled with germ balls and cercariæ in various stages of development. The anterior end is somewhat pointed, while the posterior end is rounded.

Cercaria echinocauda is similar to *Cercaria ocellata* La Valette St. George, as the measurements for this species fall within the wide range described for *Cercaria ocellata*. Both forms are provided with fin-like projections on the tail. The tail of *Cercaria echinocauda* is not very contractile, contrasting with that of *Cercaria ocellata*. The oral sucker of *Cercaria echinocauda* is also much larger than that of *Cercaria ocellata*. *Cercaria echinocauda* develops in rediæ, while *Cercaria ocellata* is found in sporocysts.

Of thirteen specimens of *Planorbis trivolvis* collected at Lawrence, Kan., October 7, two were infected with a cercaria for which I propose the name *Cercaria quieta*, because of its often remaining motionless, floating in the water for brief periods of time. Like *Cercaria inversa*, this cercaria has a bifurcated tail and swims by means of a rapid vibratile motion of this organ.

The tail is enormous in size compared to the body and is not constricted off from the body in the living specimen as is the case with other furcocercous forms. The tail of this species is never

severed from the body in the living form, and only rarely did it become lost during mounting.

The cercaria can swim either forwards or backwards. The tips of the bifurcated tail are fitted with adhesive organs by means of which they attach themselves to the substratum or other cercariæ. Both oral and ventral suckers are small and of uniform size, measuring .027 mm. in diameter.

The excretory system consists of paired ducts leading from the anterior end of the body to the junction of the body and tail, where they anastomose and extend on back to the excretory pore which opens between the forks of the tail. No excretory vesicle is present but the excretory tube is somewhat dilated just anterior to the excretory pore.

The anlage of the reproductive system is posterior to the ventral sucker. No digestive tract could be traced.

The total length of the cercaria is .8 mm. and the width is .08 mm., the main part of the tail being as wide as the body. Of the total length the body makes up one-fifth, the unbranched tail two-fifths, and the branched tail two-fifths.

The redia of this species is long and cylindrical, measuring 1.52 mm. by .2 mm. Each redia contains many cercariæ, about one-fifth of which are mature. The rediæ were so tangled in the liver that it was almost impossible to dissect them out entire.

XIPHIDIO CERCARIÆ.

My material contains three species of xiphidio cercariæ. Owing to the extreme difficulty of studying these small forms, my descriptions are in some places incomplete. I am unable to make these species fit in with previously described forms, much as they resemble forms described by Cort and Luhe.

For the first of these species I propose the name *Cercaria haskelli*, from the locality where it was found (Haskell pond). One of thirty-three specimens of *Physa gyrina* collected from this locality at Lawrence, Kan., July 12, was infected with this species.

Cercaria haskelli is a rapid swimmer, the swimming alternating with creeping movements. A marked characteristic of this species was that it could extend the tail until it was three or four times the length of the body. When this form was swimming, the body would be contracted into a ball and the tail would be very much extended.

The measurements for this species in an average state of contraction are, length .15 mm. and width .05 mm. The tail meas-

ures four-fifths the length of the body. A stylet protrudes from the region of the oral sucker. This stylet measures .037 mm. long and has a width at its base of one-fifth of the length. It tapers to a point and has no enlargements anywhere along its length.

The oral sucker is .04 mm. in diameter and the ventral sucker measures .03 mm. In longitudinal section, both suckers open into pouches wider than the external openings. There are two layers of cuboidal cells in the wall of the ventral sucker.

The muscular layers comprising the outer wall of the cercaria average .003 mm. in thickness.

The esophagus is exceedingly narrow, averaging .0015 mm. in diameter. It is grounded by a ring of deeply staining cells corresponding to the muscular pharynx seen in other forms. The esophagus broadens into a median digestive tract .03 mm. long and .0125 mm. wide.

Anterior to and dorsal to the ventral sucker are numerous unicellular glands. These are probably stylet glands, as their position is different from that of the cephalic glands described for *Cercaria inversa*, for instance. No ducts could be found leading from these glands.

The only excretory tract found consists of irregular spaces lying against the dorsal wall of the ventral sucker. In transverse section of the tail, four large central cells can be seen surrounded by a ring of muscle fibers. In some places the walls between these central cells are made up of smaller narrow cells.

The anlagen of the reproductive organs are in two masses dorsal to the ventral sucker. These masses are connected by a narrow band of similar cells.

Cercaria haskelli is found in sporocysts. They are rounded elongate sacs containing germ balls, developing cercariæ and mature cercariæ. The sporocysts are from .25 mm. to .42 mm. long and are from one-third to one-half as wide.

Of twenty-three specimens of *Planorbis trivolvis* collected at Cherryvale, Kan., October 16, five were infected with *Cercaria gregaria*. The cercariæ emerged from the snails by thousands and had the peculiar habit of massing together in the water. They would lose their tails and form such compact masses that they could not be separated without tearing the tissues apart. These masses contained from fifty to five hundred individuals each. The cercariæ remained alive in this condition for eight hours. No encystment was seen, and very few cercariæ remained for any length of time without joining with one of the masses.

This is an exceedingly minute form, measuring only .37 mm. long, including the tail, which is half the length of the body. The width is .03 mm. Both of the suckers are the same size, averaging .015 mm. in outside diameter. This form has a stylet .006 mm. long. On account of the minuteness of this form, the internal structures could not be made out clearly. The best results were obtained by staining intravitally with picrocarmine. With this stain paired masses of cephalic glands with their ducts could be made out. The tail of this form consists of large cells with a definite single row of nuclei, showing prominently in the median line.

Sectioning the snails from which these cercariæ emerged failed to reveal either sporocysts or rediæ.

Seventy-five per cent of hundreds of *Planorbis trivolvis* collected at Pratt, Kan., August 22, were infected with a small xiphidio cercaria which I propose to call *Cercaria kansiensis*. The body of this form averages .06 mm. wide and .09 mm. long. The tail in an average state of contraction is .064 mm. long.

The oral sucker is .024 mm. in diameter and the ventral sucker is .028 mm. The openings in both suckers are .007 mm. in diameter. There is a bicornuate groove in the posterior end of the body into which the tail fits.

No digestive tract could be traced, but a ring of deeply staining cells marks the region of the pharynx.

Large unicellular cephalic glands are present. They number about four on a side. No ducts could be found leading from them.

No excretory tubes could be found, but there is a large excretory bladder .01 mm. wide and .016 long, posterior to the ventral sucker. The long axis of this bladder is in a transverse direction to the long axis of the body.

The anlagen of the reproductive organs consist of two masses of cells dorsal to the ventral sucker. The posterior mass is the larger.

Special studies were made of the stylet of *Cercaria kansiensis*. It is embedded in the muscles of the thick-walled oral sucker, dorsal to the mouth opening, and can be withdrawn into a hollow receptacle. Two camera-lucida sketches (figs. 57 and 58) show the stylet extended and contracted. The stylet measures .02 mm. in length. At the base and near the point it has a width of one-sixth its length, but between these points it is narrower.

Cercaria kansiensis is found in sporocysts averaging .33 mm. long and about one-third as wide.

In all cases where this form was found, the infection was heavy, the liver of the snail being filled with almost a solid mass of the sporocysts. Estimates of the numbers of cercariæ emerging from any one snail ran from five thousand to eight thousand.

Notes.

The following notes, while adding little to this paper, might be of assistance to any one wishing to work out life histories of trematodes.

The collecting grounds from which my material was taken covered a wide range of habitats, from temporary pools and pasture streams to artificial ponds and permanent lakes.

Only two genera of snails were examined. Infection was very rarely found in young snails, and never in snails collected from temporary pools or pasture streams. Old ponds harboring fish, frogs, muskrats and water snakes usually contained infected snails.

All of the furcocercous cercariæ were found in *Physa* collected from muddy permanent ponds. The large amphistome cercariæ and the xyphidio cercariæ were found in the genus *Planorbis* in the larger, clearer lakes. Lakes of this type are inhabited by the species of water life mentioned for the other type of ponds, and in addition are frequented by migratory birds.

The heaviest infection was found the latter part of August at the State Fish Hatchery at Pratt, Kan., where the number of snails parasitized ran as high as 90 per cent.

Only one of the species studied, *Cercaria cortii*, encysted under observation, and no cysts of any of the other forms were found outside of the snail.

One specimen of *Planorbis trivolvis*, collected from pond No. 5, July 24, showed the presence in the digestive gland of large numbers of spherical cysts about .05 mm. in diameter. These cysts correspond to those of *Cercaria trivolvis* described by Cort as having been found in the body cavity of *Planorbis trivolvis*.

One characteristic of *Cercaria gregaria* possibly throws some light on the life history of the species. This is the peculiar habit that the cercariæ have of losing their tails and forming compact masses in the water, each mass containing from fifty to five hundred individuals.

The following tables will be found useful for making summaries concerning the amount and kind of infection:

Pond Index.

No.	
1–Lawrence, Kan	Haskell, east of dairy barn.
2–Lawrence, Kan	Haskell, drainage ditch, south.
3–Lawrence, Kan	Stubbs' pond, northwest campus.
4–Lawrence, Kan	Stream, Woodland Park.
5–Lawrence Kan	Horseshoe Lake, six miles southeast.
6–Lawrence, Kan	Stream northwest of Griesa nursery.
7–Lakeview	East end of road through lake.
8–Lawrence Kan	Stream near E. A. Richards', six miles northwest.
9–Lawrence Kan	Stream one-half mile southwest of stream No. 8.
10–Lawrence, Kan	Bismarck Grove, North Lawrence.
11–Lawrence, Kan	Lake north of U. P. depot.
12–Lakeview	East of depot.
13–Pratt, Kan	State Fish Hatchery, Pond No. 22.
14–Pratt, Kan	State Fish Hatchery, Pond No. 39.
15–Pratt, Kan	State Fish Hatchery, Pond No. 41.
16–Pratt, Kan	State Fish Hatchery, Pond No. 51.
17–Pratt, Kan	State Fish Hatchery, Pond No. 77.
18–Pratt, Kan	State Fish Hatchery, Pond No. 1.
19–Lawrence, Kan	Railroad, one-half mile southeast of Haskell.
20–Lawrence, Kan	Pond on East Fifteenth street.
21–Baldwin, Kan	Pond in east edge of town.
22–Baldwin, Kan	Pond southwest of depot.
23–Baldwin, Kan	Pond center of town.
24–Ottawa, Kan	Stream east of Park, near library.
25–Ottawa, Kan	Pond near race track.
26–Ottawa, Kan	River west of west bridge.
27–Chanute, Kan	Santa Fe, one-half mile north of depot.
28–Chanute, Kan	Santa Fe, north of Frisco crossing.
29–Chanute, Kan	Santa Fe, two miles north, west side.
30–Cherryvale, Kan	Lake in city limits.
31–Cherryvale, Kan	Pond one-half mile north, along Santa Fe.
32–Abilene, Kan	Engle's pond, seven miles southwest.
33–Abilene, Kan	Pond one-half mile east of R.C. Lahr, southwest.
34–Abilene, Kan	Stream four and one-half miles southwest.

Percentage of Infected Snails.

Date.	Pond.	Host.	Number of snails.	Number infected.	Species.
7– 7	1	*Physa gyrina*	25	2	*C. inversa.*
7– 7	2	*Physa gyrina*	20	1	*C. haskelli.*
7– 9	1	*Physa gyrina*	95	0	———
7– 9	3	*Physa gyrina*	50	0	———
7–10	1	*Physa gyrina*	20	0	———
7–12	1	*Physa gyrina*	33	6	*C. inversa.*
7–20	1	*Physa gyrina*	130	0	———
7–21	4	*Physa gyrina*	23	0	———
7–22	1	*Physa gyrina*	30	1	*C. inversa.*
7–24	5	*Planorbis trivolvis*	15	1	*C. magnacauda.*
7–31	6	*Physa gyrina*	6	0	———
7–31	8	*Physa gyrina*	5	0	———
7–31	9	*Physa gyrina*	5	0	———
8– 2	7	*Physa gyrina*	10	1	*C. inversa.*
8– 3	7	*Physa gyrina*	12	2	*C. inversa.*
8– 4	8	*Physa gyrina*	20	0	———
8– 4	9	*Physa gyrina*	10	0	———
8–18	10	*Physa gyrina*	10	0	———
8–18	11	*Physa gyrina*	12	0	———
8–19	1	*Physa gyrina*	100	1	*C. fusiformis.*
8–20	12	*Physa gyrina*	100	6	*C. echinocauda.*
8–28	13	*Planorbis trivolvis*	16	4	*C. kansiensis.*
8–28	14	*Planorbis trivolvis*	30	13	*C. kansiensis.*
8–28	15	*Planorbis trivolvis*	20	3	*C. kansiensis.*
8–28	16	*Planorbis trivolvis*	20	16	*C. kansiensis.*
8–28	17	*Planorbis trivolvis*	20	16	*C. kansiensis.*
8–29	18	*Planorbis trivolvis*	29	13	*C. kansiensis.*
8–29	17	*Planorbis trivolvis*	25	21	*C. kansiensis.*
				2	*C. inversa.*
8–30	16	*Planorbis trivolvis*	50	45	*C. kansiensis.*
8–31	17	*Planorbis trivolvis*	50	34	*C. kansiensis.*
				2	*C. inhabilis.*
8–31	16	*Planorbis trivolvis*	90	75	*C. kansiensis.*
10– 7	12	*Physa gyrina*	50	1	*C. echinocauda.*
10– 7	5	*Planorbis trivolvis*	13	2	*C. inhabilis.*
10– 8	19	*Planorbis trivolvis*	12	2	*C. inhabilis.*
10–12	19	*Planorbis trivolvis*	23	1	*C. inhabilis.*
10–19	21	*Physa gyrina*	50	0	———
10–19	22	*Physa gyrina*	50	2	*C. haskelli.*
10–19	23	*Physa gyrina*	50	0	*C. haskelli.*
10–19	25	*Physa gyrina*	50	2	*C. haskelli.*
10–19	26	*Physa gyrina*	50	0	———
10–19	27	*Physa gyrina*	50	0	———
10–19	28	*Physa integra*	50	2	*C. gracilis.*
10–19	29	*Physa gyrina*	50	0	———
10–20	30	*Physa gyrina*	50	7	*C. gregaria.*
10–21	30	*Physa gyrina*	27	5	*C. cortii.*
11– 9	31	*Physa gyrina*	50	0	———
11– 9	32	*Physa gyrina*	100	0	———
11– 9	33	*Physa gyrina*	25	0	———

Favorable circumstances enabled the writer to continue his investigations of the cercariæ described in this paper during the summer and fall of 1916, and as late as January 5, 1917. The vicinities of Lawrence and Pratt were resurveyed, with the results that the species found the preceding year were verified by repeated collections and comparisons. *Cercaria magnacauda* was not found this season.

Many cases of double infection were found in *Physa gyrina* from pond No. 1. These cases of double infection were confined to two groups, one consisting of an infection of *Cercaria inversa* in rediæ in the digestive gland. and unidentified cysts in the body cavity,

corresponding in size to those of *Cercaria trivolvis* Cort. The other group consisted of a combination of the above-named cysts in the digestive gland, and a cluster of much larger cysts of a polystome cercaria on the periphery of the middle part of the snail inside of the shell.

Experimental work carried on with *Planorbis trivolvis* infected with *Cercaria kansiensis* at Pratt, during the summer of 1916, showed that cercariæ were continually emerging from snails kept in wire cages suspended in the ponds at the Fish Hatchery. These snails were taken from the cages each morning and confined in watch glasses in the laboratory. No characteristic swarming was noticed, but instead a few cercariæ could be seen emerging from the snails every time they were examined.

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ACKNOWLEDGMENTS.

I want to express my thanks to Dr. W. W. Cort for his kindness in lending me slides, examining my preparations, and aiding in the identification of species. I also wish to thank Dr. H. A. Pilsbry for identifying the snails used in the studies. To Prof. Bennet M. Allen, under whose direction the work has been done, I wish to express my appreciation for his interest and constructive criticisms.

EXPLANATION OF PLATES.

With the exception of Plate VII, all figures are drawn with the camera lucida. The abbreviations are after the plan adopted by Cort.

ABBREVIATIONS USED.

ac–acetabulum.
bp–birth pore of redia.
br–brain.
c–concretions.
cg–cystogenous glands.
ccg–cephalic glands.
dc–ducts of ccg.
e–eyespot.
es–esophagus.
ex–excretory system.
exp–excretory pore.
exd–excretory duct.
exv–excretory vessel.
gb–germ ball.
i–intestinal cæcum of cercaria.
ir–intestine of redia.
la–locomotor appendage of redia.
lc–large central cells of tail.
ml–muscle layer.
os–oral sucker.
p–pigmentation.
pb–pharyngeal bulb.
pr–pharynx of redia.
ra–reproductive anlage.
s–stylet.
sr–stylet of redia.
sc–cercariæ in sporocysts.
sg–stylet glands.
sw–wall of sporocyst.
vs–ventral sucker.

PLATE I.

FIG. 1. *Cercaria cortii.* × 61.
FIG. 2. Cross section of *C. cortii* through brain. × 122.
FIG. 3. Cross section of *C. cortii* through reproductive anlage. × 122.
FIG. 4. Cross section of tail of *C. cortii.* × 244.
FIG. 5. Longitudinal section of tail of *C. cortii.* × 244.
FIG. 6. Cyst of *C. cortii*, dorsal view. × 61.
FIG. 7. Cyst of *C. cortii*, lateral view. × 61.

PLATE II.

FIG. 8. *Cercaria diastrophora* Cort. × 144.
FIG. 9. Cross section of *C. diastrophora* through oral cavity. × 288.
FIG. 10. Cross section of *C. diastrophora* through pharynx. × 144.
FIG. 11. Cross section of *C. diastrophora* through reproductive anlage. × 144.
FIG. 12. Cross section of tail of *C. diastrophora.* × 288.
FIG. 13. Immature redia of *C. diastrophora.* × 144.
FIG. 14. Mature redia of *C. diastrophora.* × 72.
FIG. 15. Longitudinal section through excretory pore of *C. diastrophora.* × 576.

PLATE III.

FIG. 16. *Cercaria inhabilis* Cort, dorsal view. × 44.
FIG. 17. Immature *Cercaria inhabilis.* × 36.
FIG. 18. Immature redia of *C. inhabilis.* × 36.
FIG. 19. Mature redia of *C. inhabilis.* × 36.
FIG. 20. Cross section of *C. inhabilis* through intestinal cæca. × 160.
FIG. 21. Cross section of *C. inhabilis* through excretory pore. × 160.
FIG. 22. Cross section of tail of *C. inhabilis* near body. × 160.
FIG. 23. Cross section of tail of *C. inhabilis* near posterior end. × 160.
FIG. 24. *Cercaria gracilis.* × 160.
FIG. 25. Redia of *Cercaria gracilis.* × 36.

PLATE IV.

FIG. 26. *Cercaria fusiformis*, dorsal view. × 72.
FIG. 27. *C. fusiformis*, ventral sucker closed. × 160.
FIG. 28. *C. fusiformis*, ventral sucker open. × 160.
FIG. 29. *C. fusiformis*, ventral sucker lateral view. × 160.
FIG. 30. *Cercaria magnacauda*. × 72.
FIG. 31. Body of *C. magnacauda*. × 260.
FIG. 32. *Cercaria quieta*. × 72.
FIG. 33. Ventral sucker of *C. quieta*. × 260.
FIG. 34. Mouth of redia of *C. magnacauda*, longitudinal section. × 260.
FIG. 35. Mouth of redia of *C. magnacauda*, cross section. × 260.
FIG. 36. Redia of *C. fusiformis*. × 30.
FIG. 37. Redia of *C. quieta*. × 36.
FIG. 38. Redia of *C. magnacauda*. × 104.

PLATE V.

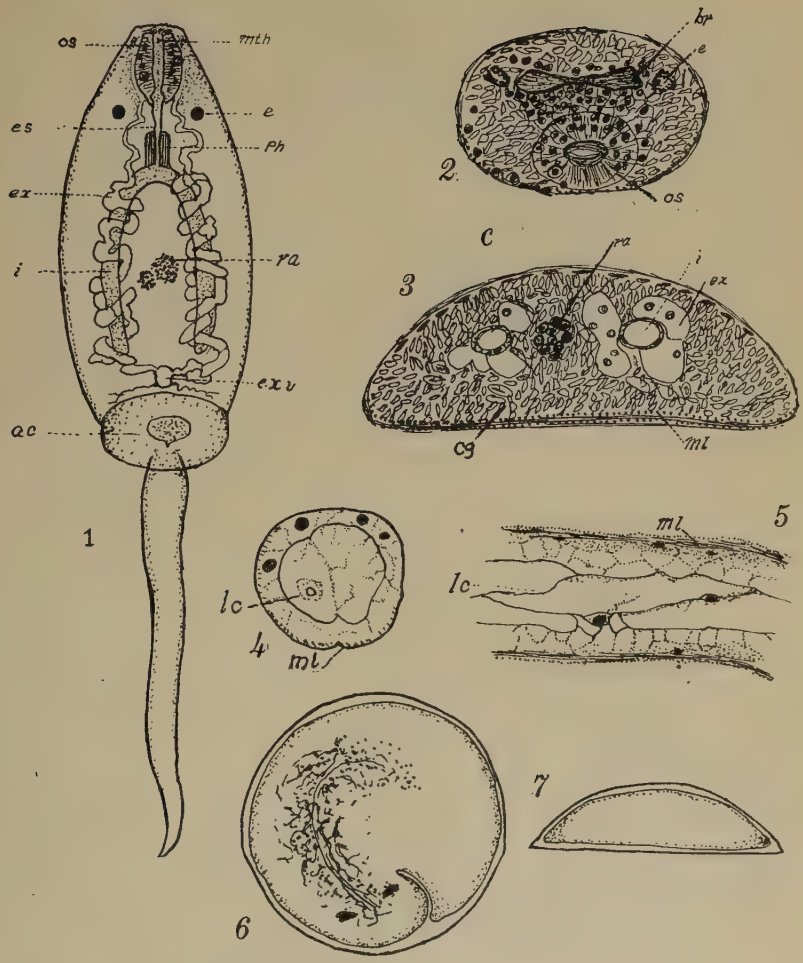
FIG. 39. *Cercaria echinocauda*. × 72.
FIG. 40. *Cercaria echinocauda*. × 72.
FIG. 41. Redia of *C. echinocauda*. × 36.
FIG. 42. Longitudinal section through *C. echinocauda*. × 160.
FIG. 43. Cross section through *C. echinocauda*. × 160.
FIG. 44. Tail of *C. echinocauda*, longitudinal section. × 160.
FIG. 45. Tail of *C. echinocauda*, cross section. × 160.
FIG. 46. *Cercaria inversa*. × 72.
FIG. 47. Redia of *C. inversa*. × 72.
FIG. 48. Cross section of tail of *C. inversa*. × 144.
FIG. 49. Cross section through cephalic glands, *C. inversa*. × 144.
FIG. 50. Cross section through oral sucker, *C. inversa*. × 520.
FIG. 51. Longitudinal section through excretory pore, *C. inversa*. × 260.

PLATE VI.

FIG. 52. *Cercaria haskelli*, dorsal view. × 144.
FIG. 53. *C. haskelli*, longitudinal section. × 160.
FIG. 54. *C. haskelli*, cross section through tail. × 160.
FIG. 55. Sporocysts of *C. haskelli*. × 72.
FIG. 56. *Cercaria kansiensis*. × 260.
FIG. 57. Lateral view of stylet, *C. kansiensis* withdrawn. × 260.
FIG. 58. Lateral view of stylet extended, *C. kansiensis*. × 260.
FIG. 59. Sporocyst of *C. kansiensis*. × 72.
FIG. 60. *Cercaria gregaria*. × 144.
FIG. 61. Longitudinal section of snail liver infected with *C. kansiensis*. × 44.
FIG. 62. Sporocyst *C. kansiensis*, cross section. × 260.

PLATE VII.

Reconstructions of the cercariæ described in the preceding pages all drawn to scale × 36. The numbers refer to the indices accompanying plates I-VI. Numbers 8′ to 56′ refer to sporocysts and rediæ corresponding to the cercariæ.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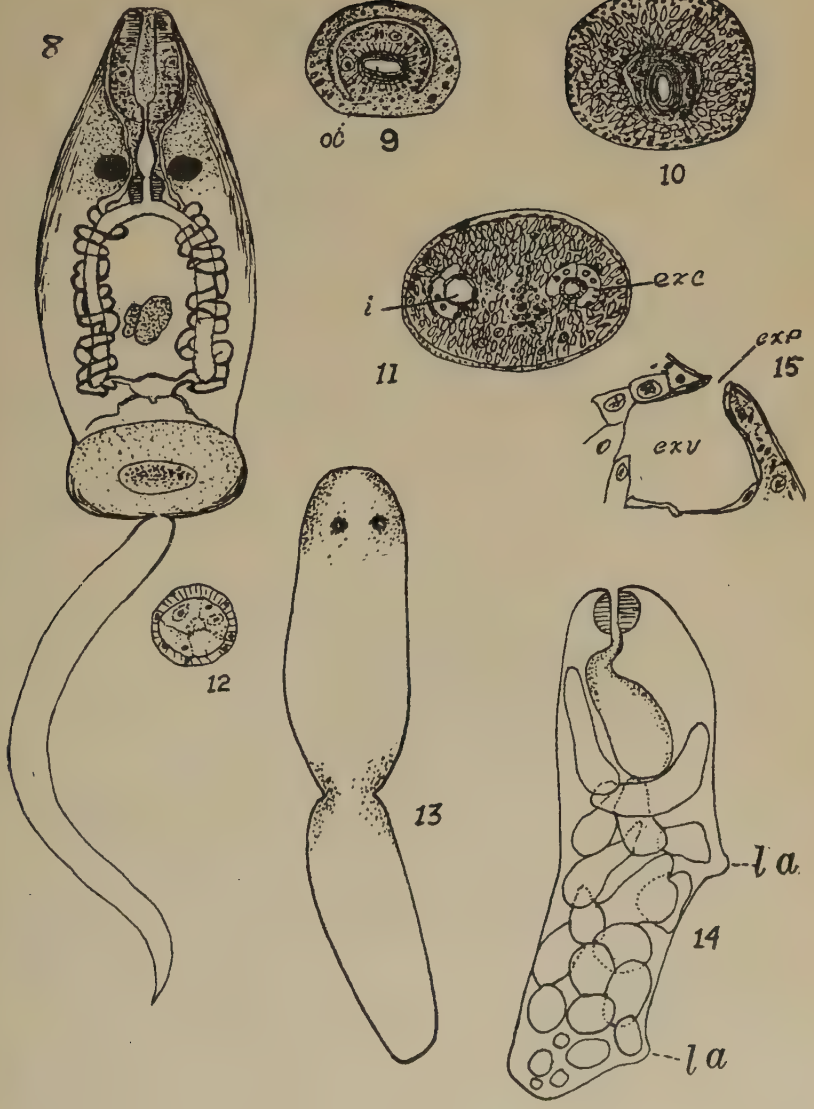
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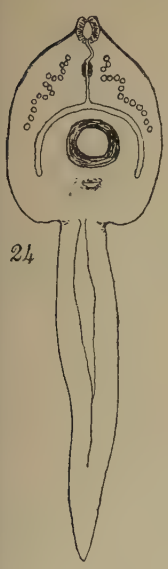

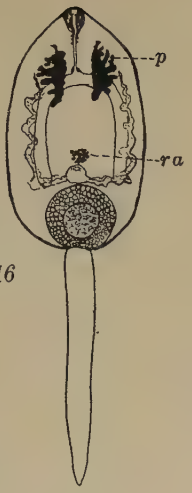

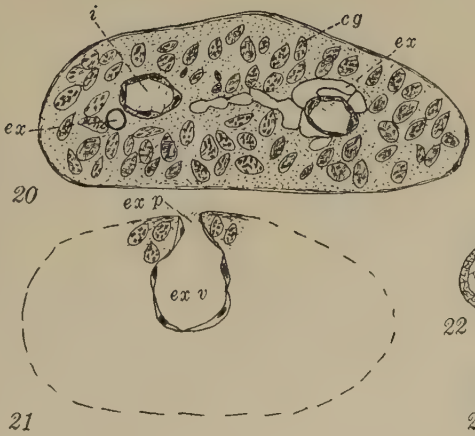

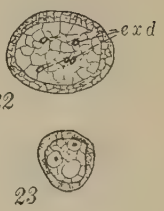

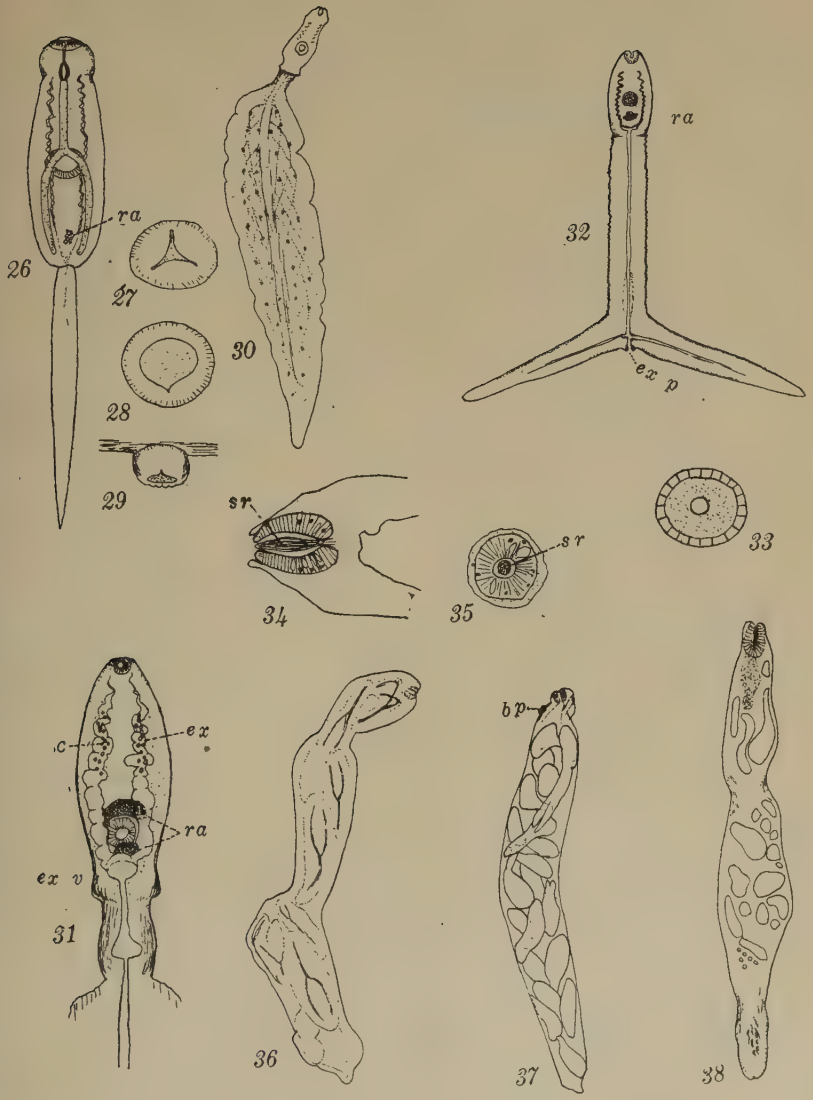
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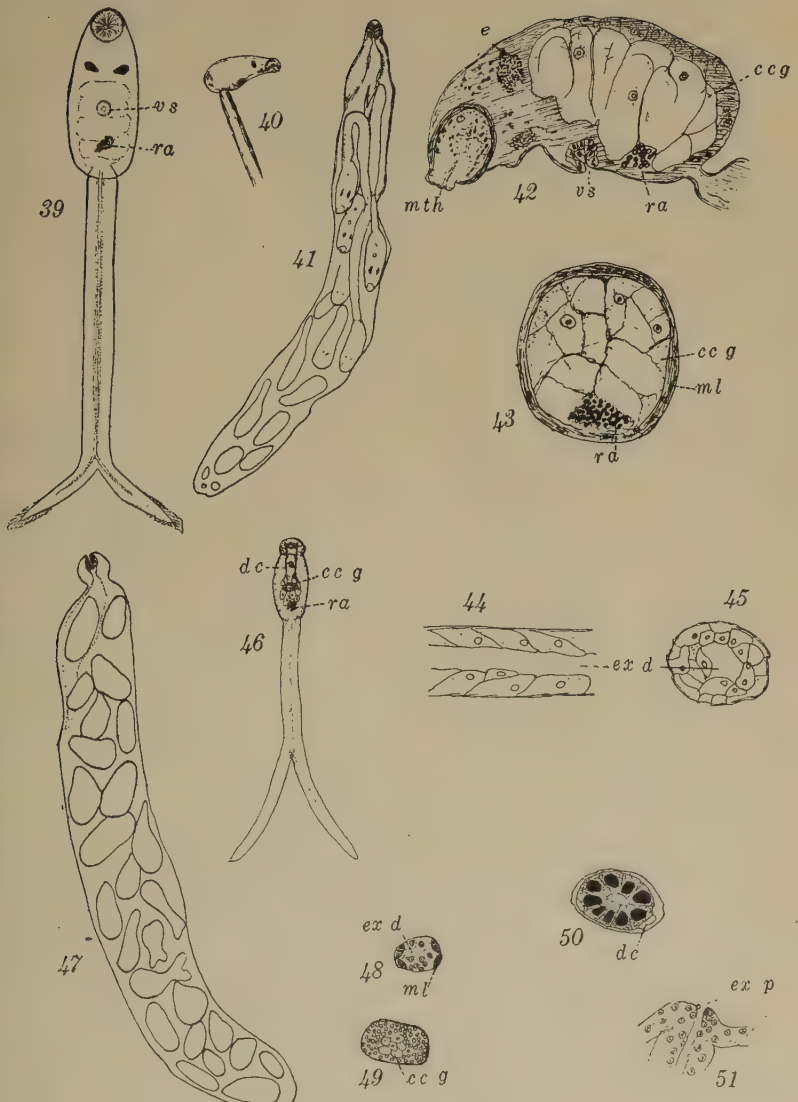
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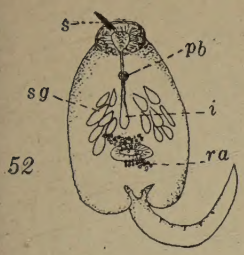

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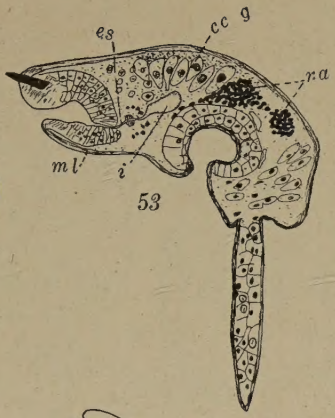

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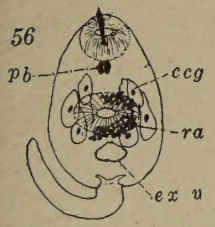

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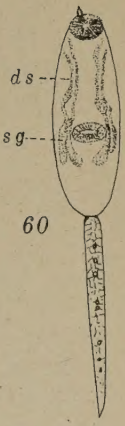

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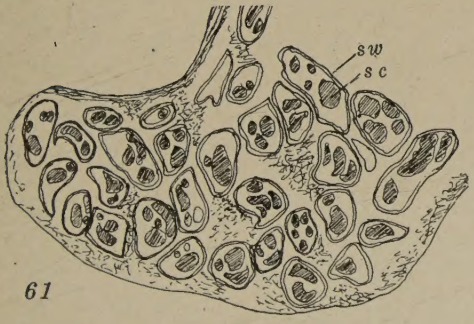

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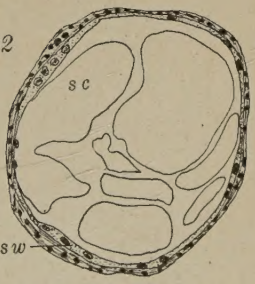

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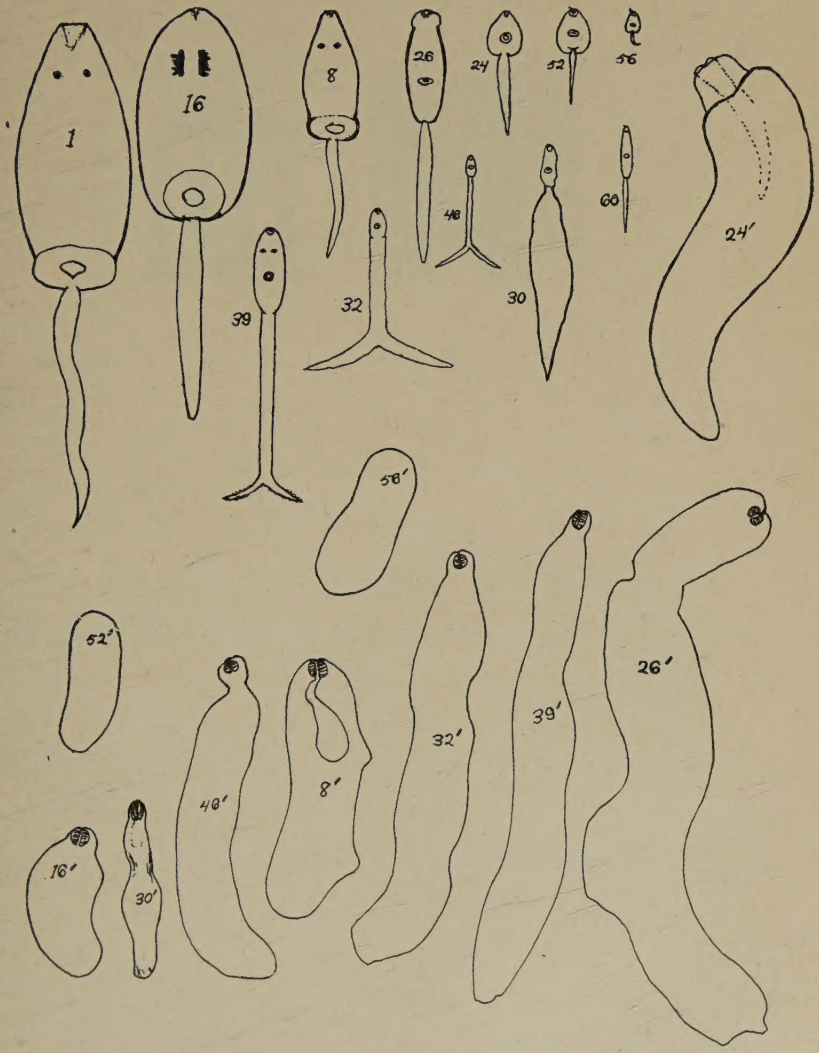
PLATE VII.